Carbon Deposition on Blade Surfaces of Laser Microactuator for Optical MEMS

Ying He*, M.Ota* and S.K.Stefanov**

*Tokyo Metropolitan University, Dept. Mech. Eng., 1-1 Minami-Osawa, Hachioji-shi, Tokyo 192-0397, Japan
**Institute of Mechanics, BASci., Acad. G. Bonchev Str., Bl.4, Sofia 1113, Bulgaria

Abstract. A laser opto-microactuator has been proposed as an Optical Micro-Electro-Mechanical-Systems (OMEMS). The rotational or twisting mechanisms of the microactuator have been discussed. For increasing the sensitivity of the actuator, the temperature difference between the front and rear blade surfaces of the actuator should be increased. Therefore, high absorption rates on the blade surface with laser beam irradiation and low heat conductivities of blade materials are needed. In the present paper experimental and numerical approaches have been carried out. For increasing the absorption rates of a laser beam on the blades of the microactuator, carbon molecules were deposited from a heated carbon fiber to substrates in a vacuum deposition machine. The deposition rates were experimentally measured and are compared with the numerical results by DSMC.

INTRODUCTION

With the coming of the 21st century, because electronic technology and the industry of mechanical information merging developed to high performance, mechanical technology is being developed and carried on to the micro mechanical technology that has the characteristic of lightweight and detailed technology. A laser opto-microactuator has been proposed as an Optical Micro-Electro-Mechanical-Systems (OMEMS) [1], [2], [3]. In order to prove a non-wiring type of energy supplying method, a kind of energy absorption film has been studied for improving the rotational characteristics of the laser beam micro-actuator. Carbon black powder that was used conventionally on the actuator turns round, so it is easy to make the carbon come off and then reduce the rotational characteristics because the carbon cannot be coated evenly. In order to solve the problem above-mentioned, a new vacuum deposition device was adopted to make a carbon film, a laser energy absorption film. The characteristics of the energy absorption film were appraised by an optical method meaning transmittance, reflectance and absorption. The numerical analysis with DSMC method was carried; meanwhile a film thickness was evaluated.

VACUUM DEPOSITION EXPERIMENTS

In the vacuum deposition experiments, deposition materials were heated in vacuum conditions under a low-voltage for heating, and the particles produced were sent towards a glass substrate, on which a film was condensed and produced in this study. CC-40F carbon coater was used instead of a conventional method fixed carbon black powders with an adhesive medicine. The carbon fiber heated by electric current evaporated carbon particles and then produced the energy absorption film for a laser beam.

The photo of a deposition machine is shown in Figure 1. After being furnished with 4 electrodes in a vacuum chamber, an alternating current was used between each electrode. The carbon fiber fixed at the electrodes evaporated the carbon particles after heating the fiber. After setting up a stage that can be moved freely in the vacuum chamber, the deposition distance between the fiber and a substrate (glass) can be fixed.

According to the film thickness of reference data, the deposition distance and the deposition pressure were designed, and then the deposition experiments were carried out. The amounts of the deposition decrease with increasing the deposition distance. In order to absorb the light energy effectively, the light energy of transmission should be reduced. Therefore the method of increasing the thickness film can be reached. The deposition experiments must be repeated many times. As shown in the figure 2, the total thickness of the film increases with increasing the deposition times. With increasing the times of the deposition, the deposition distance increases also. As shown in Figure 3, with the increment of deposition times, the amounts of the deposition increase. On the other hand, the transmittance and reflectance of the light from the deposited surface decrease, and the absorption increases. The temperature of the deposition film surface increases with the increment of the deposition times.

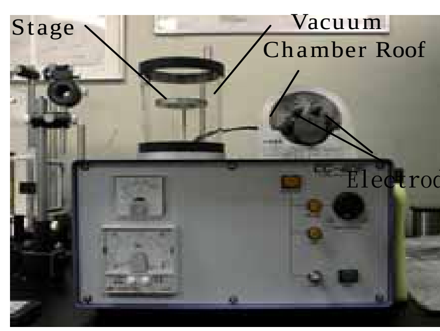

Figure 1 Photo of deposition machine

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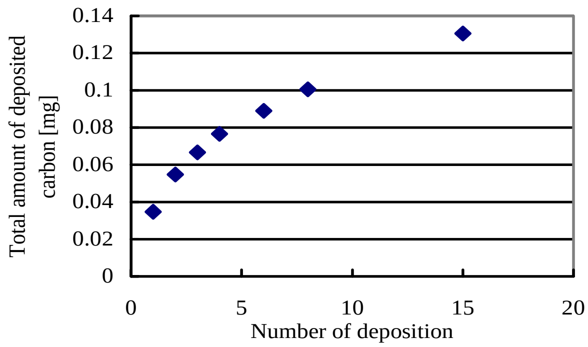

Figure 2 Dependence of total amount of deposited carbon on number of depositing times

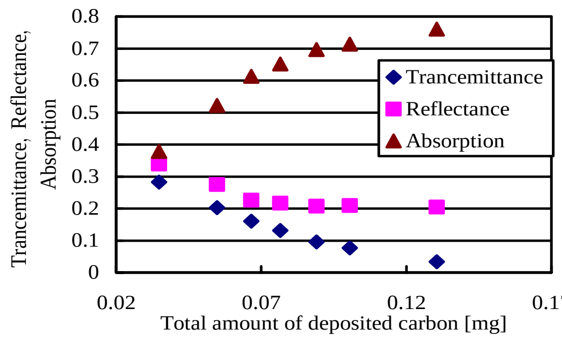

Figure 3 Transmittance, reflectance and absorption of Deposited surface

NUMERICAL ANALYSIS BY DSMC METHOD

DSMC method

Numerical analysis method (DSMC, Direct Simulation Monte Carlo) was developed to simulate the molecular motion of rarefied gases. It is the effective method to analysis the intermediate flow field [4]. The intermediate field is the one (0.01< Kn <10.0) that the probability of colliding between gas molecules and solid surfaces and the probability of colliding among the molecules cannot be neglected. The DSMC method can be used from free molecular flowing to continuum. On the other hand, in a micro field, the DSMC method can also be used in the range of the atmosphere. It is the method that tracks the individual motion of molecules and determines a macroscopic flow field. However, a large amount of molecules exist in the real physical space. Using to the DSMC method, several millions of the molecules in the physical space can be selected out. And using probability rule deriving from the gas molecular theory, the positions and velocities of molecules can be evaluated in a computational cell and the macroscopic flow field can be determined.

Numerical analysis of vacuum deposition by DSMC method

In the present research project the energy absorption film is made from the carbon molecules evaporated in vacuum. The film thickness was estimated using the DSMC method. By the flow model of CC-40F carbon coater, deposition machine, the flow inside the vacuum chamber, the temperature of the carbon fiber and the position of the substrate (the deposition distance) have been determined firstly. The film thickness was evaluated under the following two kinds of conditions：

1. The temperature of carbon fiber is 1000k, 1500k, 2000k, respectively, with the initial pressure of the chamber 4 Pa;
2.The deposition distance 40，50，60，70，80，100，200mm, respectively, with the initial pressure of the chamber 4 Pa;

In figure 4, the physical model and computational model were shown. In figure 5, the cylindrical vacuum chamber is axial symmetry, so that only one fourth of that was a computational domain. Air and carbon were set up in this boundary condition. Only the substrate can absorb the carbon particles as the solid boundary [5]. The air just diffuses and reflects on the substrate

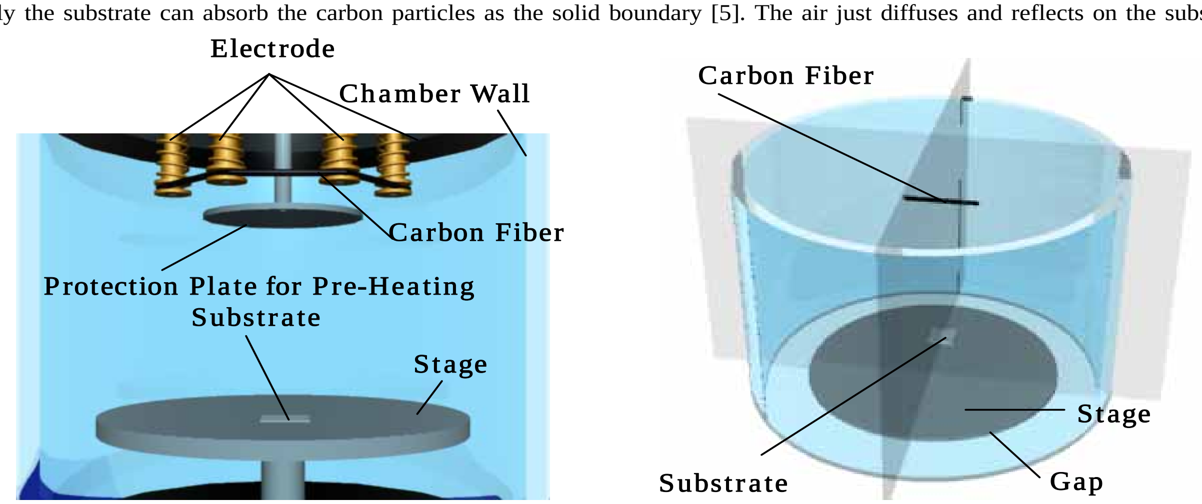

Figure 4 physical model (the left picture) and computational model (the right picture) boundary.

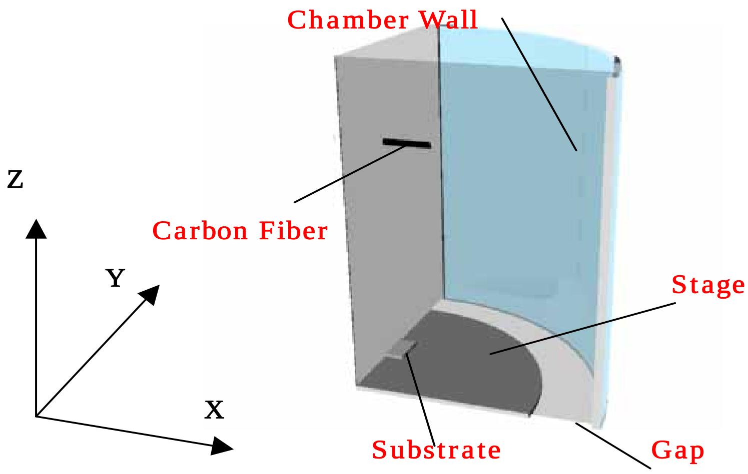

Figure 5 Computational model with axi-symmetry

Temperature effects of carbon fiber on depositions

The surface temperature of the carbon fiber was settled as 1000k, 1500k, 2000k, respectively, and the other temperature of the boundaries were 288k. With changing the surface temperature of the carbon fiber, the number of the carbon molecules flying into the substrate changes in a certain period. As shown in figure 6, when the surface temperature of the carbon fiber with the same deposition distance increases, the number of the carbon to the substrate also increases. When the particle evaporates from the fiber, the evaporating temperature determined the particle's energy and velocity. Being higher the surface temperature of the carbon fiber, the energy of the evaporated carbon molecule is bigger; moreover, the film thickness on the substrate is thicker. From the numerical analysis, the followings can be indicated:

1. Air spreads out in a circle-wise shape and an equi-density of the air is eccentric around the carbon fiber with the temperature of the carbon fiber increasing (shown in figure 7).
2. Increasing with the surface temperature of the carbon fiber, the particle temperature on the substrate increases. Because of the collision in the chamber, both carbon particles and the air decrease, the probability of colliding among high velocity carbons and the substrate increases (shown in figure 8).
3. Increasing with the surface temperature of the carbon fiber, the flux on the substrate increases gradually along with the way out to the chamber (shown in figure 9).
4. Increasing with the surface temperature of the carbon fiber, the density of the carbon decreases along with the stage boundary (shown in figure 10).

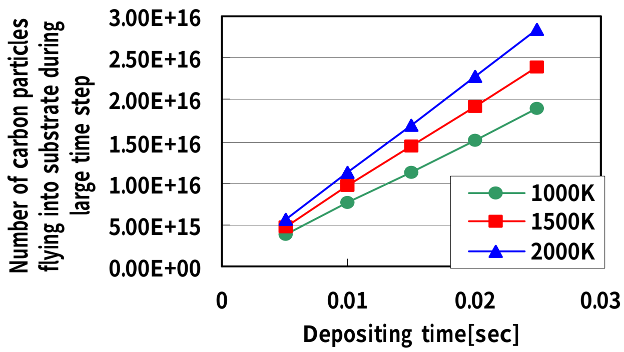

Figure 6 Effects of carbon fiber temperature on number of deposited carbon molecules

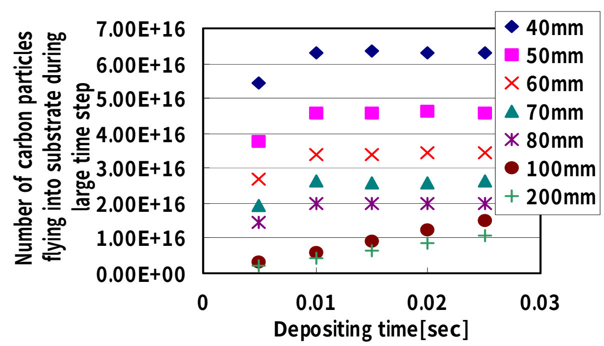

Figure 11 Effects of deposition distance on number of deposited carbon molecules

Effects of deposition distance on deposited carbon molecules

The surface temperature of the carbon fiber was settled as 1500k, and other temperatures were 288k in the boundary. According to the deposition principle, with increasing the deposition distance, the probability of colliding among the evaporated particles and the environment molecules in the chamber increases. Therefore the number of the carbon flying into the substrate decreases. From figure 11, with the increment of the deposition distance, the number of the carbon flying into the substrate decreases at the same temperature. The effects of the deposition distance on the carbon number flying into the substrate in 1.3 seconds were estimated. As shown in figure12, the results by the experiments are mutually in agreement with the numerical ones. From the numerical analysis, the followings can be indicated:

1. Being longer with the deposition distance, the equi-density curve of the gas in the chamber spread out eccentric around the canon fiber (shown in figure 13).
2. Increasing with t he deposition distance, the particle's temperature on the substrate decreases (shown in figure 14).
3. Increasing with the deposition distance, the flux on the substrate decreases gradually along with the way out to the chamber (shown in figure 15) and the density of the carbon increases along with the stage boundary (shown in figure 16).

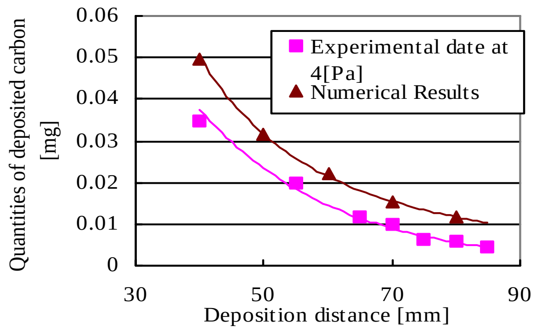

Figure 12 Dependence of deposition distance on deposited carbon weight

CONCLUSIONS

The total number of the carbon particles arriving to the substrate in experiments was compared to the estimated value by the DSMC method. The numerical results agree with the experimental data qualitatively. The number of the particles converges with the time progress. With thicker the film thickness, sputtering phenomenon happens easily. With increasing the fiber temperatures, the number of the carbon molecules colliding against the substrate and the carbon film thickness on the substrate increase. The carbon molecule number is dependent on the distance between the fiber and the substrates.

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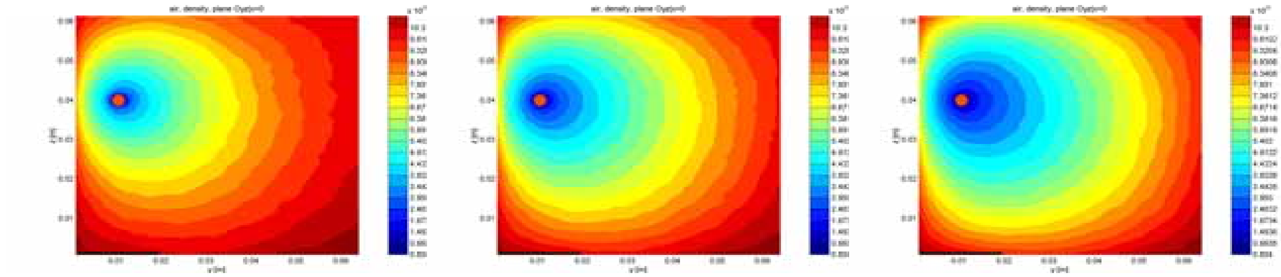
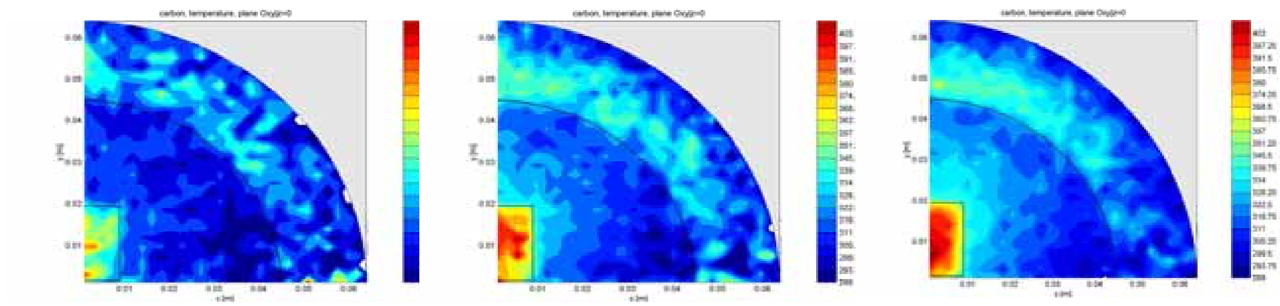


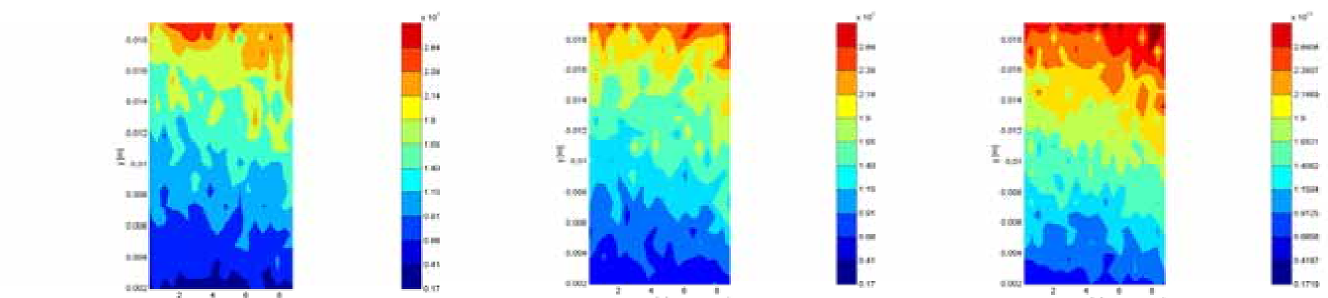
1000K 1500K 2000K

Figure 7 Number density of air on plate x=0



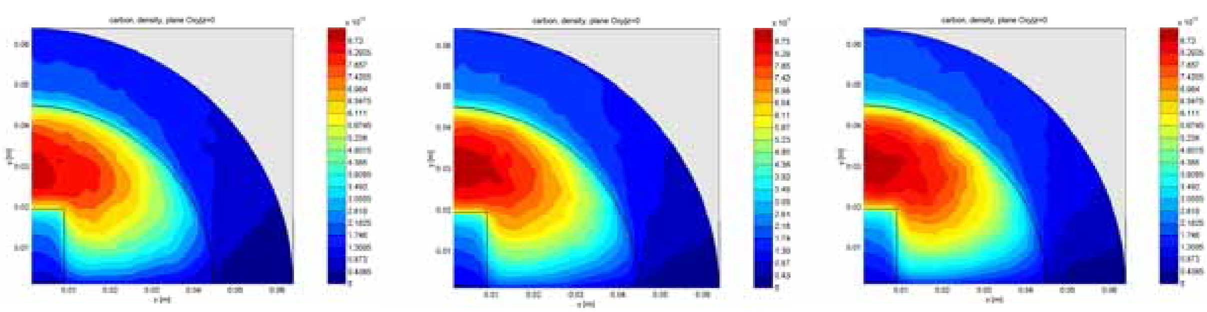
1000K 1500K 2000K

Figure 8 Temperature of carbon on z=0



1000K 1500K 2000K

Figure 9 Flux on substrate



1000K 1500K 2000K

Figure 10 Number density of carbon on z=0

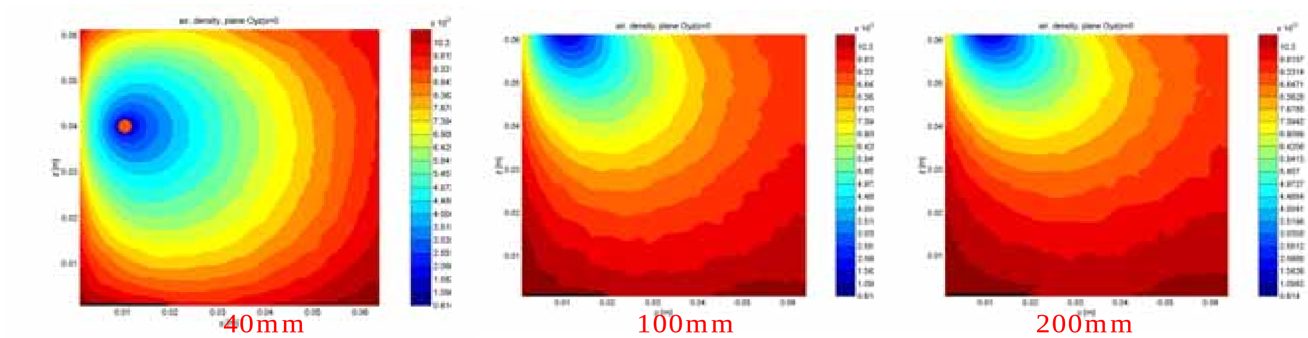


Figure 13 Number density of air on plate x=0

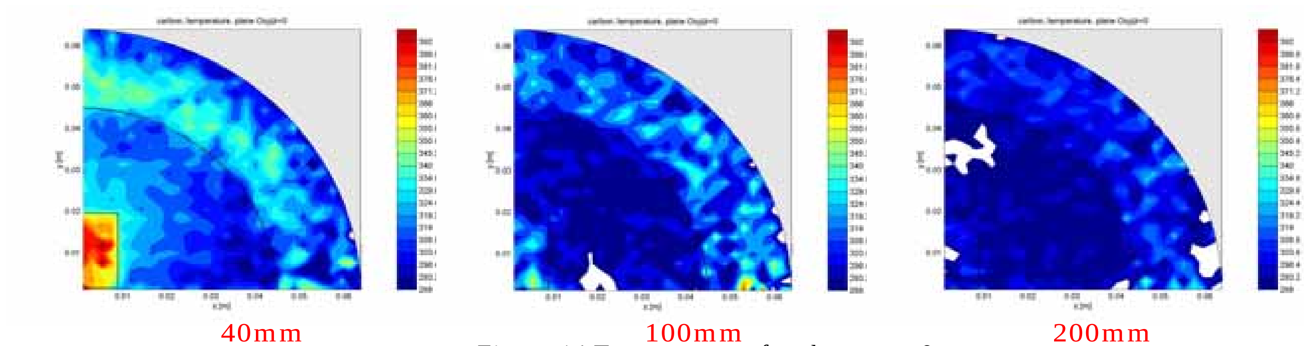


Figure 14 Temperature of carbon on z=0

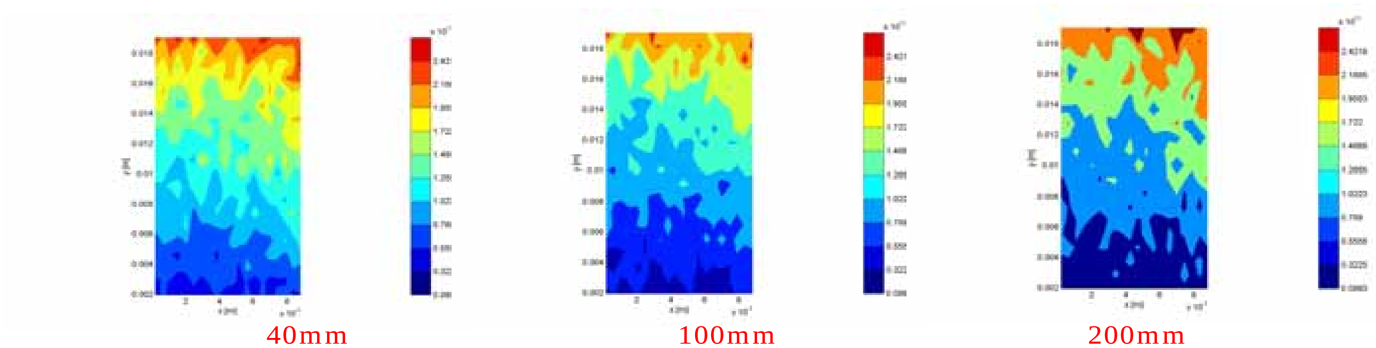


Figure 15 Flux on substrate

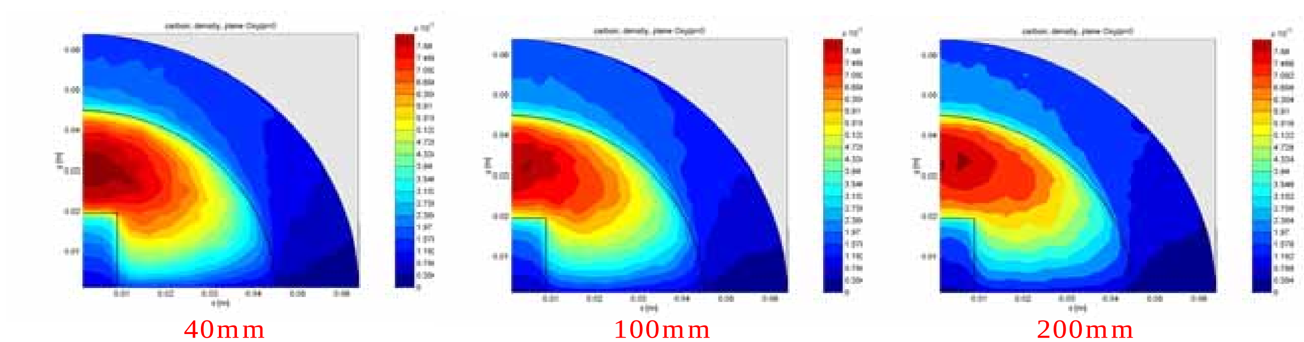


Figure 16 Number density of carbon on z=0